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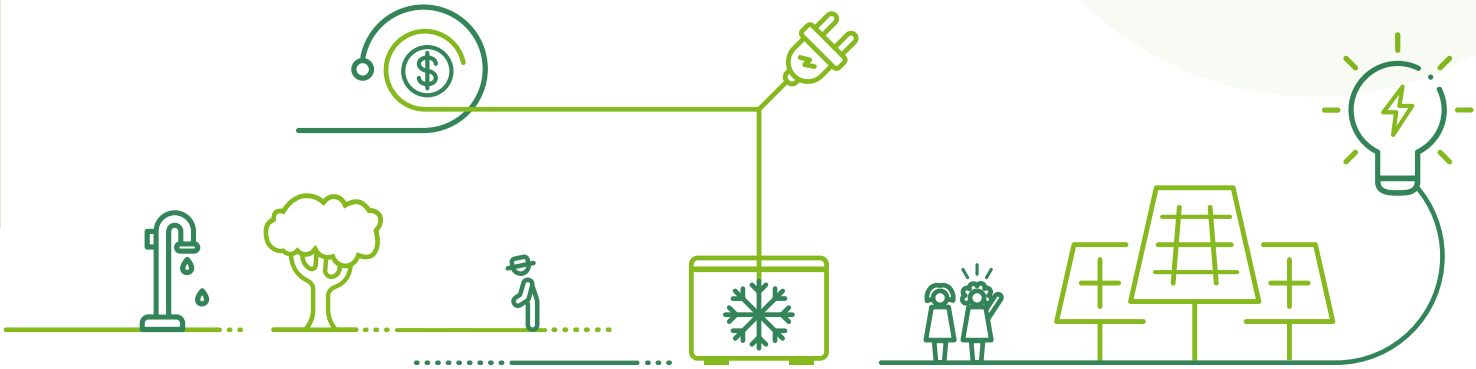
GRÜNE BÜRGERENERGIE
(GREEN PEOPLE'S ENERGY)
THEMATIC KNOWLEDGE PRODUCT

Productive Use of Energy (PUE) in the Agricultural Sector

Learnings from the Green People's Energy programme



Purpose of the thematic knowledge product

About 600 million people in Sub-Saharan Africa (SSA) lack access to electricity. Electrification is particularly low in rural areas, where less than 20 % of the population has access to electricity (IEA et al.). For people living far from the national grid in rural areas with low population density, access to electricity through grid extension is rarely economically viable. While stand-alone off-grid systems based on renewable energies could bridge this supply gap, they remain unaffordable to many. Consequently, this also applies to productive technologies powered by off-grid systems which yield significant potential for the economic development of local enterprises and the improvement of communities' livelihoods.

Against this background, the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) programme for "Green People's Energy" (Grüne Bürgerenergie, GBE) aims to improve access to electricity with decentralised renewable energy (DRE) in rural SSA. It applies market-based approaches involving local key stakeholders, including the population, authorities, agricultural cooperatives, financial institutions and solar companies. GBE promotes DRE systems in rural areas in nine African countries: Benin, Côte d'Ivoire, Ethiopia, Ghana, Mozambique, Namibia, Senegal, Uganda and Zambia. Particular attention is paid to promoting local value added through productive use of energy (PUE).

To make the learnings and results accessible for the future conceptualisation of such projects, four thematic knowledge products look into the intermediate impacts and lessons learned from selected GBE interventions and identify key success factors for why and how which technologies, support measures and funding approaches work.

This Knowledge Product focuses on stand-alone **productive use of energy** appliances for farmers and small businesses, such as solar water pumps/solar-powered irrigation systems (SPIS), solar cooling, and solar drying. Sector-specific challenges and intervention approaches are described first before findings from the GBE programme are presented to enrich the sector discussion.

Productive use of energy

Since the 1970s, rural development projects relied on the assumption that enabling access to energy would not only improve people's livelihoods in general terms but bring along opportunities to use energy productively for an improvement in rural incomes. As some PUE applications reached business viability, and digitalisation, pay-as-you-go (PAYG) and credit scoring technologies were taken up by PUE suppliers, this market segment also started raising investors' interest. In 2021, 7.7 million USD of investors' grant capital were provided to PUE companies, and major donors (World Bank, IKEA Foundation, EnDev, GIZ, UK Aid and Power Africa) have committed funding to support the uptake of PUE appliances (Lighting Global et al., 2022). Despite the increased interest, barriers to PUE uptake persist on several levels. On the end-user level, these comprise lack of awareness, technical and commercial skills and a very limited access to credit. Suppliers, on the other hand, often struggle to gather the necessary working capital (e.g., to purchase stock, offer PAYG/credit schemes or to cover installation costs), which then limits their ability to provide end-user financing.

Rural communities are especially disadvantaged in this regard as suppliers are also hesitant to invest in costly last-mile structures and their poor market linkages reduce opportunities to generate income via product value addition. In addition, the prevalence of inexpensive, but low quality and fake products in many rural markets leads to negative user experience and distorts the reputation of PUE products (EnDev, 2020; ESMAP, 2008; Global Distributors Collective, 2022; Mohapatra et al., 2020; Wearne, 2021; Wearne et al., 2022).

A literature review has found that the following approaches are the ones most commonly used by development partners when promoting stand-alone PUE appliances:

APPROACH 1:
Business case demonstration and business development support

In most rural areas, farmers and rural entrepreneurs are lacking the technical and commercial skills to assess the profitability of a PUE investment, identify products of good quality, as well as to operate and maintain a PUE technology sustainably. This can be addressed by PUE technology and business case demonstrations which showcase to farmers and rural entrepreneurs the commercial potential of mature PUE technologies through joint implementation of real-life demonstration projects.

For such business case demonstrations, technology assessments and cost-benefit analyses help to identify mature PUE technologies (A2EI, 2021; Flammini et al., 2019, 2018). Once technologies are identified, it is helpful to involve PUE product and/or service companies on a competitive basis, highlighting to them the commercial benefits of showcasing their products to rural customer groups. The interaction with farmers and rural entrepreneurs requires expertise on rural production processes, agricultural value chains, and market linkages. Farmer cooperatives or associations can be used both as direct partners and as facilitators for beneficiary selection. Business development services (BDS) are essential to integrate PUE investments into existing business plans. In parallel, technical trainings on operation and maintenance of the PUE technology help farmers to run these sustainably. A typical challenge faced within this approach is upscaling: many demonstration projects lack a clear strategy on how to use private sector and market-based approaches to reach scale beyond a number of demonstration projects (Wearne et al., 2022).

Beneficiary from a women farmer group that was given a solar pump to grow vegetables

APPROACH 2:
Supply-side subsidies for market building

Supply-side subsidies work as an incentive for PUE suppliers to tackle specific challenges and market barriers such as lack of rural distribution structures, limited customer awareness of PUE or ability to pay for a relatively pricy product. If they are disbursed only once pre-defined results are delivered and verified, they classify as results-based; most often, incentives are paid upon verified sales to end-customers or even upon verification of installation of the product at the customer's premises. It is not uncommon to see a staggering of incentives: some percentage being paid on import, the bulk on sales, and a minor part on good quality after-sales and warranty services.

Depending on the maturity of the PUE market, supply side incentives can include business challenges for innovative product/service development (USAID, 2020a, 2020b, 2018) or results-based financing (RBF) for the extension of product/service offers into rural areas. RBF incentives can be technologically and geographically neutral or steered towards specific technologies, customer groups, or geographic areas. Incentives offered can be lump-sum or expressed as percentage of retail or free-on-board (FOB[1]) prices, possibly with top ups for additional criteria (e.g., remoteness, target group, financing terms). They can be disbursed for investments in stock, at point of sale, or after intermediate impacts have become verifiable. Beyond incentives, also the equity and working capital requirements of PUE companies need to be addressed, e.g., by linking to or introducing loan facilities and credit risk guarantees (EnDev, 2021). A typical challenge faced by this appraoch is insufficient demand density in rural areas which prevents PUE companies from breaking even on their investments in rural sales and service structures and endanger the sustainability of the market once subsidies stop being paid after project closure.

APPROACH 3:
Demand-side subsidies for access to finance

Demand-side subsidies are grants forwarded to end-consumers and entrepreneurs to enable them to invest in the purchase of an energy access product that would otherwise have prohibitive upfront costs (Africa Clean Energy et al., 2020; Gogla, 2021; SEforAll and Climate Policy Initiative, 2022; Tearfund, 2020). There are various delivery mechanisms for channelling the grant to the end-customer, e.g., vouchers and cash-transfers or via intermediaries, such as suppliers, who have to forward the grants to end-users by lowering their retail prices respectively. If these kinds of grants are made results-based, thus being paid, i.e., once PUE equipment is sold to the end-user, these are generally referred to as demand-side RBF (as opposed to supply-side RBF discussed above). Key design considerations for a demand-side RBF approach are: selection of PUE products with economic potential but not yet fully commercialised; incentive level calculations; eligibility criteria for end-users (e.g., having a pro-poor focus) and – most importantly – a sustainable subsidy strategy that does not distort markets. Ideally, subsidies are provided only on a temporary basis with a clear phase-out plan; and are targeted at vulnerable customer groups who would otherwise not be able to participate in the market (ESMAP, 2022; Gogla, 2021; Reiche and Teplitz, 2009). Facilitating access to credits for end-users, e.g. through assistance on identifying suitable financing offers and approaching financial institutions, is also subsumed under this approach.

OUTLOOK:
Ecosystem approaches as the new standard for PUE promotion

To overcome the multi-dimensional barriers in PUE promotion, comprehensive, integrated or so-called ecosystem approaches are an alternative to the single-purpose interventions discussed before. The idea is to tackle PUE promotion not as a single issue (energy) intervention, but as a cross-sectoral approach, linking energy, rural development, and SME support. It is therefore important to use and develop synergies in order to create an integrated, sustainable approach to PUE promotion, e.g. by providing policy advice on PUE product quality standards and tax and tariff exemptions alongside the project or by benefiting from cross-sectoral activities like cooperating with agricultural extension services. To make an approach as holistic and long-lasting as possible, it is useful to employ supply as well as demand-side subsidies to accelerate market development and to offer technical assistance in the form of demonstration projects that provide a model for technical and financial viability. (Borgstein et al., 2020; EnDev, 2020; USAID, 2020c).

1 FOB indicates "that the liability and ownership of the goods have been transferred from a seller to a buyer. This means that if the goods get damaged or destroyed during the shipping, the seller is not liable. The buyer is the one who pays the shipping cost from the factory and the entire responsibility of the goods is on the buyer […]." (The Economic Times, 2023)

Tackling such projects from multiple angles rapidly increases their complexity which needs to be considered by development organisations in the project design phase. Fortunately, the PUE sector is evolving and is lately seeing PUE hardware and service providers (e.g. cooling as a service) gaining grounds and reaching unprecedented operational scale (Global Distributors Collective, 2022).

This is an opportunity to re-focus development partners' interventions towards mobilising the increasingly agile private sector. This may entail providing private sector players with easier access to blended finance, match-making with investors, facilitating linkages to agricultural markets, and a general shift from project-level targets to PUE market acceleration (Wearne et al., 2022).

GBE's approaches to promoting PUE

GBE has promoted various schemes for the promotion of PUE in rural areas, particularly in the agricultural sector. For this Knowledge Product, a comparative analysis of eight specific case studies of GBE-interventions was conducted. For the case studies, the target groups were approached with a quantitative survey and central key project stakeholders were interviewed qualitatively.

Although most of these GBE-interventions have an element of business case demonstration and/or business development support, the approaches applied vary significantly from project to project, with most of them consisting of combinations of the approaches described above. In many cases, these have been complemented by traditional technical assistance activities such as training measures (beyond those already constituting part of the activities for business case demonstration and business development support) and awareness raising. In fact, all eight GBE-interventions analysed in detail for this Knowledge Product can therefore be considered as following a multi-dimensional ecosystem or cross-sectoral approach, as described above. These GBE-interventions, their respective approaches, target groups and promoted types of PUE appliances are reflected in *Table 1 below*.

The main achievements, impacts as well as lessons learned and recommendations which can be drawn from the case studies are presented in the following section.

Table 1: Overview of approaches used in the GBE-projects

Country	GBE-project	(Main) Type of PUE Appliance	Main Target Groups	Financing and payment of users' contribution	PUE prices
BENIN	**Results-Based Financing (RBF) Mechanism for the Sale of Productive Equipment** › Supply-side RBF › Facilitation of access to credits through partnerships with MFIs › Awareness raising on the user side	Mainly solar pumps and solar cooling	Smallholder farmers; SME	Credits from MFIs; some suppliers offer PAYG	Market prices
CÔTE D'IVOIRE	**Results-Based Financing (RBF) Project in the field of Solar Cooling for Productive Use** › Support for the development of business plans of users; matching suppliers and users; › Supply-side RBF › Training of sales agents and technicians; training of the beneficiaries for the appropriate use of PUE appliances	Mainly solar cooling; also solar pumps and sprayers	SME; smallholder farmers; cooperatives	PAYG offered by larger solar companies	Market prices
ETHIOPIA	**Solar Drying Technology for Agricultural Cooperatives in Ethiopia (pilot project)** › Support in demonstrating the feasibility of a new drying solution based on the use of a solar-powered drying tunnel, including training on operation and simple servicing and maintenance tasks › Solar dryers provided as full grants	Solar drying	Agricultural cooperatives; Agricultural Research Centre	No own user share	Full grants

Country	GBE-project	(Main) Type of PUE Appliance	Main Target Groups	Financing and payment of users' contribution	PUE prices
GHANA	**Promotion of Productive Use Appliances in Ghana through Results Based Financing** › Support in selecting SPIS for farmers' specific needs and training on the use and maintenance of SPIS › Demand-side RBF (40 % of the system price for male and 50 % for female customers) › Awareness raising for farmers	SPIS	Smallholder farmers	Up-front payment of farmers' own share	Subsidized prices for selected farmers
MOZAM-BIQUE	**Developing the Solar Irrigation Business Case in Gaza Province (pilot project)** › Technology providers are given the opportunity to develop a business model and test the market for SPIS. For this purpose, 111 people received training in various fields › Specifically, 7 received training in drilling techniques, 21 were technicians from suppliers specialising in SPIS, 42 received training in agriculture, including teachers, local farmer-technicians and SDAE extension workers › In addition, 14 participants were involved in training sessions centred on the financial aspects of investments in small-scale solar irrigation, while 27 individuals took part in a training session aimed at showing the lessons learned from the project	SPIS	Smallholder farmers	PAYG offered by suppliers for farmers' own share	Subsidized prices for 100 farmers
NAMIBIA	**Program for Development of Solar PV Systems for Productive Use in Rural Commercial Enterprises** › 20 rural farmers are supported in assessing their business case for SPIS › Demand-side RBF (50 % of the system price)	SPIS	Smallholder farmers	Up-front payment of farmers' own share through own funds or credits from financial institutions	Subsidized prices for 40 farmers
SENEGAL	**Energy for the Resilience of Small Producers in the Milk Value Chain in Senegal** › Support to livestock farmers in rehabilitating irrigation areas for fodder production by using SPIS. Training is provided on business and management topics to transform the farmers to entrepreneurs. Farmers are also trained in the maintenance of the SPIS › SPIS provided as full grants	Mainly SPIS; (also solar system for business centre to power sewing machines and refrigerator)	Smallholder livestock farmers; (also local communities, particularly women and youth)	No own user share	Full grants
UGANDA	**Solar Irrigation Planning Development and Operation and Maintenance, Training Programme** › 40 selected farmers receive individualised advice on the feasibility of implementing SPIS including a technical design and financial analysis › This is complemented by training on how to best integrate SPIS into their agricultural activities and O&M › The 40 selected farmers receive a subsidy of 70 % of the system cost › Training for technicians who design, install, and maintain SPIS; teachers from Vocational Training Institutes; local government personnel	SPIS	Smallholder farmers	Up-front payment of farmers' own share through own funds or credits from financial institutions	Subsidized prices for 40 farmers

Main project results

Project Achievements

In total, GBE promoted 1600 solar PUE appliances. The PUE appliances are primarily more than 600 solar pumps / SPIS used by farmers or agricultural cooperatives to water their fields, and almost 400 solar fridges which are usually used by shop owners and traders to cool beverages and food which spoils quickly in the heat, such as vegetables and fish. Furthermore, 375 solar sprayers, 130 sewing machines, 14 mills, 9 solar dryers as well as 7 welding machines have been taken into operation. The total capacity of the photovoltaic (PV) panels powering these appliances amounts to more than 1.1 MWp.

Intermediate Impacts

In order to have more representative findings on further intermediate impacts, the results from the quantitative surveys of 18 GBE-interventions promoting PUE were analysed in an aggregated manner. A total of 290 beneficiaries participated in the survey: 42 % of them were farmers, 32 % SMEs, 16 % cooperatives, and 10 % others, for instance technicians.

Figure 1 shows the kinds of PUE appliances which these respondents have installed. As for the eight case-study projects, the main use is pumping/irrigation (45 %). This includes simple solar-powered water pumps as well as more complex SPIS with additional irrigation elements, such as piping and water tanks. Solar appliances for refrigeration came second with 27 % of the total appliances installed.

51 % of beneficiaries surveyed state that the solar PUE appliance replaced (41 %) or partly replaced (10 %) an older appliance or power source. In almost half of these cases, these were fuel-powered systems (such as diesel-pumps), while about 30 % were mechanical appliances (such as manually operated pumps), and the remaining 20 % were old solar-powered appliances.

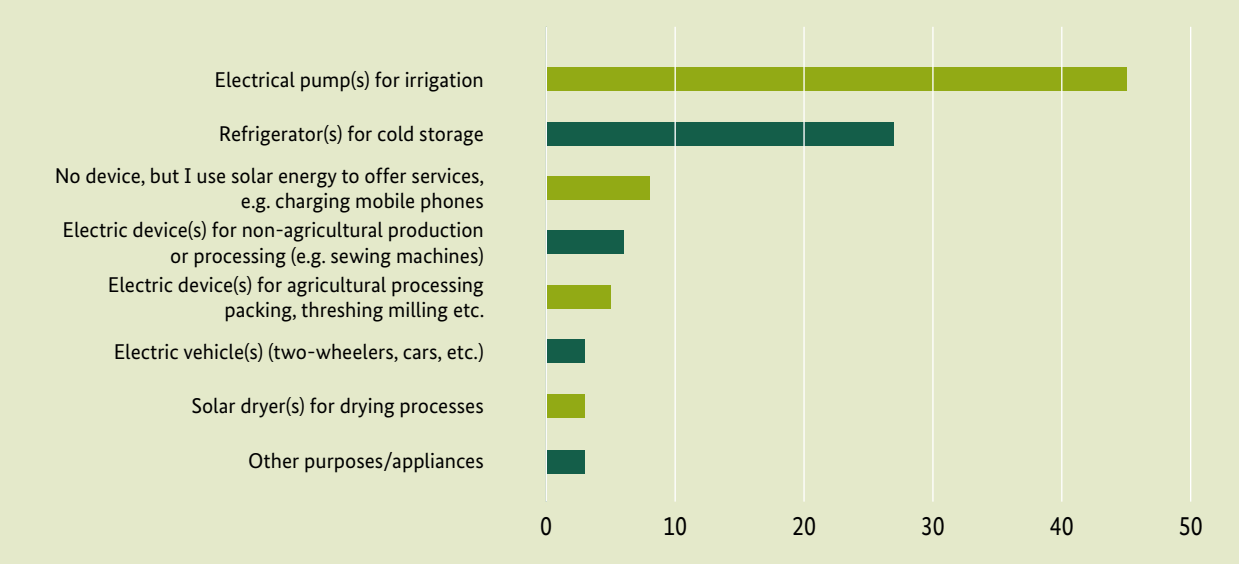


Figure 1: Solar PUE appliances installed by survey participants

66 % of the productive users surveyed state that their running energy costs have been reduced thanks to the solar PUE appliances. Usually this is due to the replacement of fossil-powered units, such as diesel pumps, which have high fuel costs and require frequent costly maintenance and repair[2]. An increase in energy costs was perceived by 13 % of the beneficiaries, most likely those for whom the PUE-appliance did not replace a previous power source and who therefore previously had no costs at all for energy, but now had to incur costs for the maintenance of their PUE appliance.

76 % of the beneficiaries surveyed state that their productivity has increased as a result of the use of PUE appliances. This can have a variety of reasons. Particularly, due to the lower operating costs of solar pumps in comparison to diesel-powered units, farmers can now irrigate more frequently, allowing them to either farm larger areas or increase yields while maintaining the same farm size. Solar pumps allow farmers to extend their activities both timewise and in terms of variety as they can increase their number of harvests and introduce new crops. Owners of solar fridges/freezers are on the other hand able to offer new products, such as ice and cold beverages, which increases their business output and in some cases the solar solution even allows them to open a business in the first place. Furthermore, energy cost savings can have a positive spill-over effect on business productivity, as end-users often use the budget freed up from energy expenditure to reinvest in improving their businesses. On the other hand, 7 % of the respondents state that their productivity decreased which can mainly be attributed to improper use of solar PUE appliances and certain technical limitations which will be discussed further down in the section on lessons learned.

Cost reductions and gains in productivity lead to increased income which was reported by 75 % of the surveyed beneficiaries. In addition, by extending agricultural production over larger periods, income has become more stable throughout the year for many farmers.

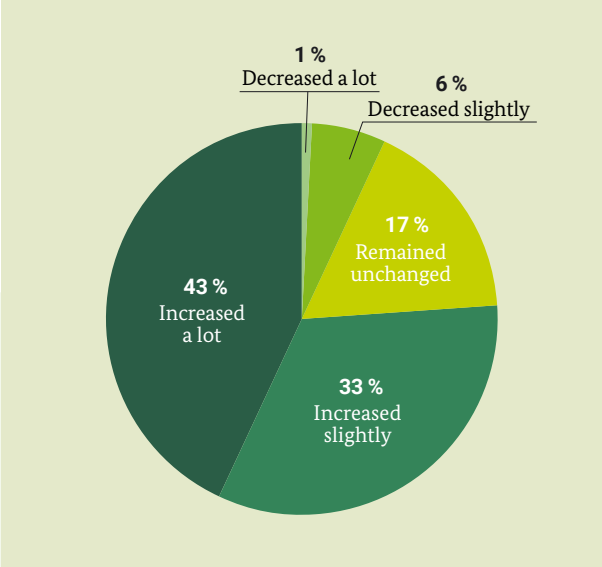


Figure 3: Impact of solar PUE appliance on productivity

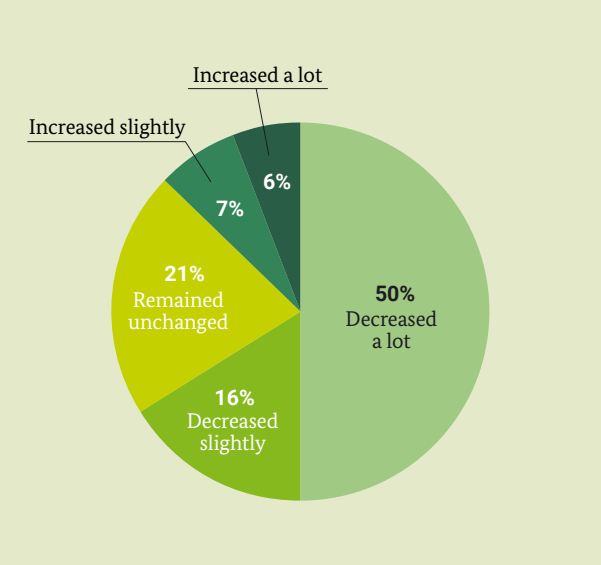


Figure 2: Impact of solar PUE appliances on running energy costs

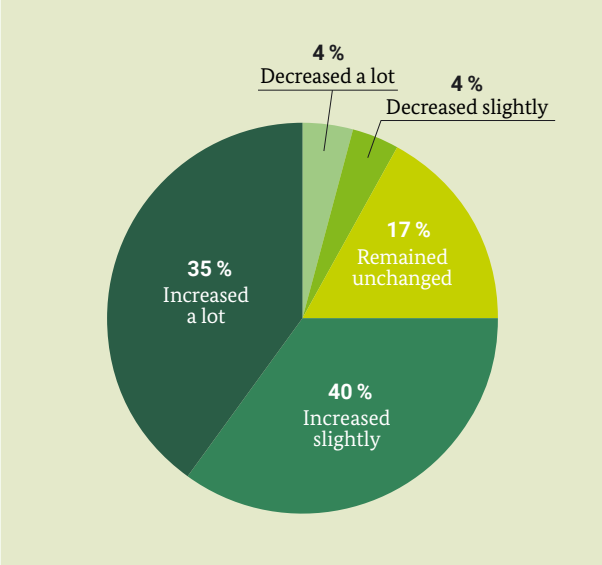


Figure 4: Impact of solar PUE appliance on income

2 Diesel generators and other motors generally require more maintenance and repair due their mechanical complexity with many moving parts. PV panels on the other hand follow a much simpler technical design.

In terms of impacts on labour and employment, the survey results paint an ambivalent picture: While 39 % of the surveyed beneficiaries hired additional labour force, 42 % were able to save on labour. This can be illustrated using the example of SPIS: On one hand, the resulting increases in agricultural production require additional labour for cultivation and harvest and other activities such as removing weeds, which also grow faster with improved irrigation. On the other hand, efficiency gains – for instance by not having to operate manual pumps or spend time purchasing diesel fuel anymore – reduce the need for human workforce. As the data shows, these opposing effects seem to approximately cancel each other out.

Further impacts captured by the quantitative surveys are reflected in *Figure 5 below*:

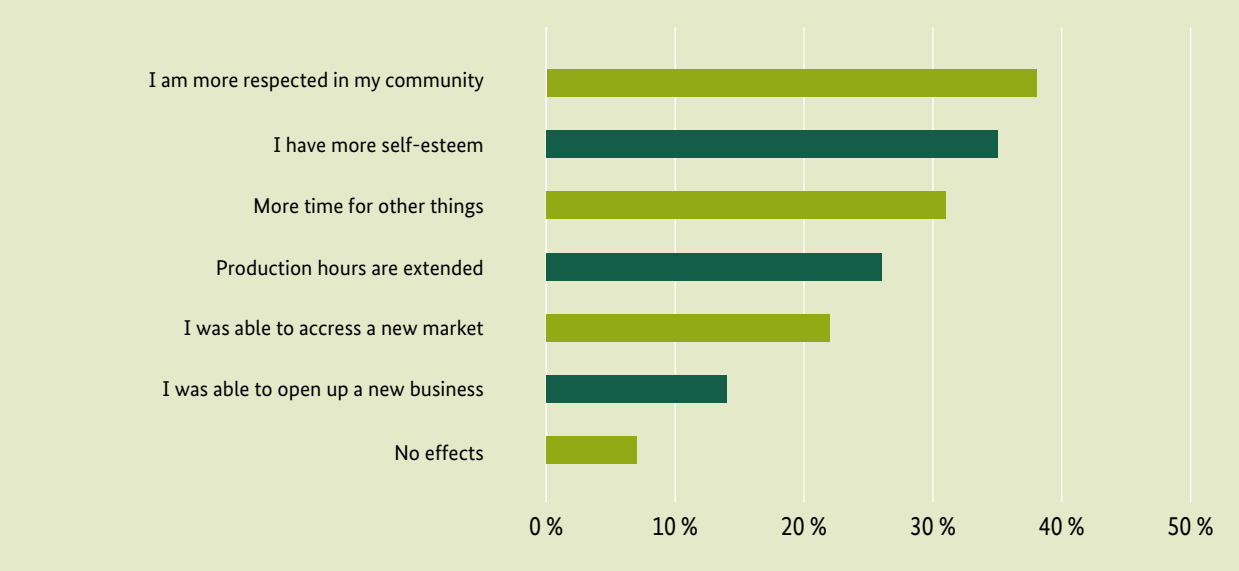


Figure 5: Other impacts of the solar PUE appliances

Particularly, the benefits in terms of saved time through the use of solar pumps due to not having to purchase diesel fuel anymore or carry out frequent repairs on diesel generators were emphasised also in the qualitative interviews with project beneficiaries. While some use this time gained to spend more time with their families and participate in social activities, other recipients have started new additional businesses, further increasing their income. Increased income has enabled some families to access quality education for their children and necessary healthcare services.

In terms of impacts on the local population it was reported that by enabling farmers to grow crops throughout the year, solar pumps and SPIS contribute to **long-term food security and increase the autonomy of the rural communities**. Furthermore, the increased availability of products, such as fresh beverages, fish, and medicine, made possible through the use of solar cooling, has contributed to further improvements for the rural population.

Also, a few **unintended impacts** have been observed. For instance, a livestock farmer in Namibia who installed a SPIS with support of GBE mentioned that he has planted 300 timber trees in addition to irrigating his fields, because he now has water available "for free". Another example of unintended benefits is that some farmers who had smaller PV systems before replaced these with the help of GBE and sold their old systems to other farmers at a low price instead of throwing them away. This further increased the number of farmers now using solar energy.

However, unintended impacts are not always positive as another example from Namibia shows, where very poor farmers and shop owners could not afford to purchase solar PUE appliances while the more affluent benefitted from their availability made possible through the RBF-incentive provided by GBE. This led to social envy in the communities and complaints to participating solar companies.

Although no specific case has been reported to date under the GBE programme, solar-powered water pumps bear the risk of an overuse of water resources as there is no direct cost associated with every litre consumed.

88 % of the respondents of the quantitative survey stated that their PUE appliance was still working at the time of the survey. 6 % of the respondents said that it is partly working, and another 6 % replied that it is not functioning, either not anymore (2 %) or never has worked at all (4 %). Ensuring sustainable operation of solar PUE appliances will be further discussed in the following section.

Key findings and lessons learned

1. Awareness raising and demonstration – key to building market confidence

First and foremost, for interventions aiming to increase the use of solar PUE appliances, the target end-users first need to be informed about the solar technologies themselves. There is often a need to overcome prejudices and misperceptions of risk, caused by bad experiences with low-quality solar equipment, and a need for awareness raising as potential users simply do not know that PUE appliances exist and how they work.

Experience from the assessed GBE-projects shows that this is best done through awareness-raising campaigns and demonstration events during which projects inform about the benefits which solar PUE appliances can bring to farming or business activities and how they can be profitably integrated into existing structures.

If possible, awareness raising campaigns should be carried out in cooperation with government and local agencies, building knowledge within their organisations, so that corresponding measures can continue beyond the duration of the intervention.

For demonstration events in rural areas, using mobile solutions such as trucks equipped with respective appliances is recommended, like those used in the GBE-intervention in Uganda. This way PUE solutions can be displayed in rural villages with maximum efficiency.

Demonstration projects in fixed locations, on the other hand, should choose a setting as practical as possible to demonstrate the use of solar PUE appliances in real life to attract and inform other potential users. Finally, such demonstration projects should be carried out with carefully selected end-users to ensure that pilots run smoothly and serve as best-practice examples to others. For instance, these should be run by farmers who are able to carry out proper maintenance, willing to let others come and visit their plot, and who have a good reputation in the community. A GBE-project in Kenya[3] (not included in the list of projects in table 1) found that the best way is to go via so called “lead farmers” who are also showcasing other innovations to their fellow community members.

Training on a solar dryer piloted and tested in Ethiopia

3 Kenya is not a GBE focus country, but GBE Small Projects Fund has supported projects outside the nine focus countries.

2. Improved business cases increase acceptance

Solar PUE appliances are often not being used continuously. In combination with the high investment costs for the solar technology, this can make for difficult business cases. This is probably most pronounced in the case of solar drying solutions which are only used for a few weeks a year. Although this technology can significantly reduce harvest losses and increase revenues accordingly, solar dryers currently need to be heavily subsidised. In fact, in the GBE-pilot intervention in Ethiopia, the solar dryers were provided to the end-users completely free of charge. However, for broad replication to take place, these systems need to be brought closer to economic viability.

Use of grain mill showcased by the receiving cooperative in Senegal

Apart from pursuing cost reductions, for instance through the production of local components, which is currently being studied in Ethiopia, further direct measures can be taken to improve the business case for farmers. Particularly, it is recommended to use the solar panels of PUE appliances for other productive purposes during the rest of the year to increase the potential benefits. The solar panels could be used, for instance, to power irrigation pumps or refrigerators. Furthermore, renting solar dryers to other farmers against a fee can also contribute to improving the system's profitability.

Similarly, in Uganda, it was observed that several farmers who purchased solar pumps under the GBE-project are now lending these to other farmers against a fee. This proves that collective use of pumps can work and improves the business case for the users.

Another example comes from the GBE-project in Benin where, in some cases, the solar fridges come with a mobile phone charging kit which creates an additional potential source of income for shop-owners.

Therefore, maximising the use of the energy produced by the solar panels by combining them with different PUE appliances or through shared use and rental models, can significantly contribute to improving the business case which is the most important factor for their acceptance and widespread use.

3. Promotion linked to tailored end-user financing solutions

Even with a persuasive business case, high costs for procurement of solar PUE appliances represent the main challenge for the beneficiaries surveyed, with one third finding it hard to pay for their systems. Interestingly, this was also observed in some GBE-interventions where end-user subsidies were provided, lowering their own financial contribution. For instance, in Ghana, GBE contributed 40 % – 50 % of the total price of the SPIS as an RBF, which was paid to the companies after successfully testing and commissioning the installed SPIS. The farmers had to pay only the remaining share. However, since their contribution had to be made up-front as a lump sum, 68 % of the farmers found this to present a major challenge.

Smallholder farmers generally have limited cash flow, and this is closely linked to the cropping seasons. Therefore, giving farmers the possibility to pay their contributions in instalments and linking these to the times of harvest can be a significant relief for farmers struggling to make lump sum payments. Corresponding support in establishing such financing schemes should therefore often be provided in parallel to other measures promoting the use of PUE appliances.

In three of the analysed GBE-interventions (Benin, Côte d'Ivoire, and Mozambique), PAYG-solutions were offered by (some) suppliers to their customers, thereby making the systems much more affordable for their clients. These are also amongst the GBE-projects which were most effective in terms of the number of PUE appliances installed, with 150 appliances installed in Côte d'Ivoire, followed by Benin with 140, and Mozambique with a total of 52 SPIS. Thereby, these three projects alone account for 69 % of PUE appliances installed across all eight GBE-interventions analysed for this Knowledge Product. With this in mind, it seems reasonable for development projects that integrate the supply-side into their approach to identify and target particularly those suppliers who are willing and able to provide rate-payment plans to their customers. If needed, suppliers can also be supported in establishing PAYG-financing options for their customers. Compared to financing PUE appliances through credits from (micro-)

finance institutions, PAYG-schemes have the advantage of greater simplicity and therefore attractiveness for the beneficiaries who have to deal with less actors. A description and assessment of different approaches to promoting end-user financing possibilities for PUE appliances can be found in the corresponding **↗ Knowledge Product on the Energypedia Financing Topic Page**.

4. RBF-schemes designed to maximise impact

Four of the eight GBE-projects analysed for this Knowledge Product are based on RBF-schemes. Two of these consisted of supply-side RBF-incentives to de-risk the market for solar companies to commercialise innovative solar PUE appliances and venture into remote areas. These were coupled with awareness-raising for and facilitation of access to credits for end-users through partnerships with MFIs (Benin) and support for the development of business plans and training on the appropriate use of PUE appliances (Côte d'Ivoire).

The other two RBF-schemes consisted of payments made by GBE to the solar companies, which then passed these on to their customers as price reductions. These are therefore classified as a demand-side RBF. In Ghana, this was combined with further support to end-users through awareness raising, support in selecting appropriate PUE appliances for their needs and training on the use and maintenance of the appliances. In Namibia, the RBF-scheme was complemented by support to selected rural farmers in assessing their business case for PUE appliances.

Table 2 below shows the supply-side RBF type and *Table 3* presents the demand-side RBF by technologies expressed in percent of the sales price to the clients:

			Incentive in % of FOB price	
Country	**GBE-Project**	**RBF-type**	**Solar Pumps**	**Solar Cooling**
BENIN	Results-Based Financing (RBF) Mechanism for the Sale of Productive Equipment	Supply-side	34 %	21 %
CÔTE D'IVOIRE	Results-Based Financing (RBF) Project in the field of Solar Cooling for Productive Use	Supply-side	50 %	40 % (large companies) 60 % (small companies)

Table 2: RBF supply-side types and incentives in GBE interventions

			Incentive in % of FOB price	
Country	**GBE-Project**	**RBF-type**	**Solar Pumps**	**Solar Cooling**
NAMIBIA	Program for Development of Solar PV Systems for Productive Use in Rural Commercial Enterprises	Demand-side	50 %	–
GHANA	Solar Pumps for Irrigation in Ghana	Demand-side	40 % (male users) 50 % (female users)	–

Table 3: RBF demand-side types and incentives in GBE interventions

Based on the experiences made by GBE, the following considerations should be taken into account when designing RBF-schemes:

→ 4.1 Suppliers need support for preparatory site visits

Firstly, it needs to be ensured that the PUE appliances offered by the suppliers to the users are adequately designed for the desired purposes (in terms of capacity, functionality, etc.). As the GBE-project in Ghana experienced, simply obtaining information from farmers without visiting the sites has proven to be insufficient, as the information provided is often not reliable or incomplete, thereby leading to incorrect selection and dimensioning of the PUE appliances. It is therefore recommended that the suppliers carry out a site visit to their customers before preparing a specific offer. This is also supported by experiences made by the GBE-intervention in Namibia, however with the caveat that this comes at prohibitive costs and effort for the solar companies which would need to travel hundreds of kilometres – sometimes just to find out that the client is not suitable for a solar installation. It is therefore worth considering including financial support for such preparatory site visits in RBF-schemes. If deemed necessary, the system configurations proposed by the solar companies can be checked by an independent consultant.

→ 4.2. Suppliers need support to finance their stock

In all RBF-schemes analysed for this Knowledge Product, the incentives were paid out only after the appliance had been installed and verified through GBE. Especially in Benin and Namibia this caused difficulties for the suppliers which had to somehow finance their stock up-front, which presented a challenge particularly for smaller suppliers. These problems were magnified in cases where the installations could not be completed for reasons not within the suppliers' responsibility (for example, where end-users claim to be able to carry out some of the installation or preparatory work themselves in order to save costs but are ultimately unable to do so). This leads to the conclusion that, especially in nascent markets, RBF-incentives (be it supply- or demand-side) need to go hand in hand with investment facilitation for solar companies to finance their stock of PUE appliances. Some GBE interventions focused on improving financing access for SMEs, more details are described in the **↗ Knowledge Product on the Energypedia Financing Topic Page**.

→ 4.3. RBF-incentives need to be simple and precise

In Namibia, several different incentive amounts ranging between 20 % and 50 % were tested, depending, for instance, on the size, capacity, or number of appliances sold. However, these turned out to be too complex for everyone involved in the implementation and eventually a general 50 %-incentive was selected.

Generally, RBF-mechanisms need to be simple in order to raise the interest of companies to take part. For instance, solar companies which participated in the RBF-scheme in Namibia reported that the administrative procedures defined by GBE were too complicated. Not only were the contents of the contract difficult to understand, but proving the companies' track record for eligibility required a lot of cumbersome paperwork.

Although incentive systems should be designed as simple as possible, an incentive system that is too simple can also lead to unintended consequences. For example, in Benin some suppliers chose to install very small batteries in their solar fridges which impacted the autonomy of the appliances. This was likely a result of the incentive structure which did not differentiate between systems of different capacities. Since small batteries cost less than larger ones, while the incentive remained the same, suppliers were able to maximise their profits at the expense of the clients. For one, this leads to the general conclusion that specifications for PUE appliances participating in RBF-schemes should be as precise as possible without losing too much of the mentioned simplicity.

Furthermore, when designing the incentive system, it is necessary to analyse exactly what is going to be subsidised. In Côte d'Ivoire, for example, the subsidy was very deliberately paid on the FOB price, because (i) the only justification to provide is the invoice from main suppliers, facilitating the controlling and (ii) counting a subsidy on costs that may vary (e.g. transportation and customs) and which sometimes are even linked to corruption costs is avoided.

→ 4.4. Communication with target group is key

In Benin, the RBF-mechanism led some clients to believe that the GBE-project was paying the full price of the solar appliances to the suppliers. These clients became reluctant to pay their share of the system cost which caused further dissatisfaction at the level of the solar companies. It should therefore be ensured that the users' financial obligations are clearly communicated in projects using RBF-mechanisms and it seems that this is best done by the development partners themselves.

Generally, it should be considered by development organisations to carry out awareness raising and publicity measures for end-users themselves or through appropriate local partner associations instead of leaving this to the solar companies. For example, in Namibia, the solar companies were asked to advertise their products as well as the subsidy to end-users by themselves. However, due to the additional effort and costs this implied, most companies were not able to carry out such measures.

Therefore, development partners taking the responsibility for such tasks (at least initially) can ensure that the RBF-mechanism is made known and well understood by potential rural beneficiaries.

Demonstration of solar water pump to rural beneficiary group

5. Long-term functionality defines the success of interventions

Collaborative projects to promote PUE appliances can only be considered successful if the systems they support are functioning properly in the long term. Only then will users benefit from the positive impacts described above, and only then will PUE appliances gain widespread acceptance, leading to their replication by other users. The following measures can be taken by development partners in this regard.

→ 5.1. Ensuring high-quality components and installation

Ensuring the use of high-quality products can be achieved by defining minimum technical quality standards to be met by all suppliers wishing to provide solar PUE appliances under the individual support scheme. Wherever possible, and with a view to up-scaling results, technical quality standards should be introduced not only for the cooperation project itself, but also at national level. Assisting public partners in developing national-level standards and certification mechanisms can have a significant impact on quality control. However, this can be a tedious undertaking requiring time and the involvement of a broad range of stakeholders, such as government authorities and agencies, financial institutions, development organisations and NGOs, and solar companies. Therefore, this can usually not be tackled in the scope of relatively small cooperation projects like the individual GBE-interventions. However, the VeraSol quality assurance program, launched by the World Bank and other organisations, has developed quality standards for standalone solar energy kits as well as PUE appliances. These standards can be used as a basis for defining minimum technical quality standards on a project or national level.

Apart from the quality of the solar PUE appliances themselves, their proper installation is another aspect which needs to be ensured. In the GBE-intervention in Benin and Côte d'Ivoire, both aspects are integrated in the design of the RBF. The definition of minimum eligibility requirements ensures the use of quality products through experienced companies. The quality of the installations, on the other hand, is made sure of by the fact that the incentives are paid out only after the appliance has been installed, audited, and verified by an independent technical expert. However, since only few solar PUE appliances with good quality were available in Benin, the GBE team worked to introduce new brands and established links between distributors and manufacturers to introduce products that meet the requirements. Côte d'Ivoire has also tested some new brands of equipment through partnerships with CLASP and VeraSol.

→ 5.2. Demanding and communicating warranties

Another instrument to ensure proper functioning of solar PUE appliances is demanding a warranty from the supplier. In the GBE-projects analysed for this Knowledge Product, these range from one to three years. During this period, the supplier is responsible for carrying out any major maintenance and repair work required to ensure a smooth initial operation of the solar PUE appliance. For this to be effective, suppliers should be selected who are located in the project region with competent staff who can react quickly to their customers' needs and have spare parts in stock to be able to carry out repairs without delay.

Moreover, end-users need to be aware of the warranty and how to claim it, which is not always obvious. In fact, the quantitative survey shows that only 77 % of the end-users say that the supplier has offered a warranty at all. While this may be true for some of them, it was also found that some users simply did not know about the warranty, or simply did not understand how it works and how it could benefit them. Companies should therefore communicate this relevant information clearly to end-users. For example, one option would be to include warranty information and the supplier's contact details in maintenance manuals which are handed over to the users, as was the case, in the GBE-intervention in Ghana. In this project, the suppliers of the solar PUE appliances were also obliged to carry out regular performance checks during the warranty period, to ensure that the system is performing optimally, going beyond the normal warranty requirement of fixing problems only when they occur.

Specifically in RBF-approaches, another measure to ensure that suppliers fulfil their warranty obligations is to link a part of the results-based payment to the end of the warranty period, thereby providing an incentive for reliable and timely maintenance of the equipment when needed. Theoretically, RBF implementers can also make communication on warranties and after-sales services a requirement for incentive pay-out, so companies are rewarded for good communication and service. However, it should be noted that complicated or lengthy pay-out mechanisms may cause difficulties (see findings above).

→ 5.3. Training for end-users

As with most technical equipment, the responsibility for correct use and maintenance to ensure that it has a long life lies largely with the end-users themselves. Most of the GBE-interventions analysed for this Knowledge Product addressed this issue by ensuring that users receive training on simple maintenance tasks such as cleaning solar panels and filling up battery water. Providing users with maintenance manuals that are easy to understand further increases the likelihood that their PUE appliances continue to function properly, particularly once the warranty period and corresponding responsibilities of the supplier have expired.

Solar water pump training on a demonstration field

If major maintenance or repair work is required after the warranty period which cannot be carried out by the users themselves, they have to contact the supplier and pay for such services. However, according to the results of the quantitative surveys, only 64 % of the end-users make financial provisions or save reserves for such services. It is therefore recommended to emphasise this topic in user-trainings on operations and maintenance.

Finally, only if PUE appliances are used properly, they will contribute to increasing productivity and income, which in turn will improve the financial capacity of users to pay for maintenance and repairs after the warranty has expired. The correct use of PUE equipment should therefore always be part of end-user training. A few particular issues in this context are discussed *below*.

6. Using Solar Pumps efficiently

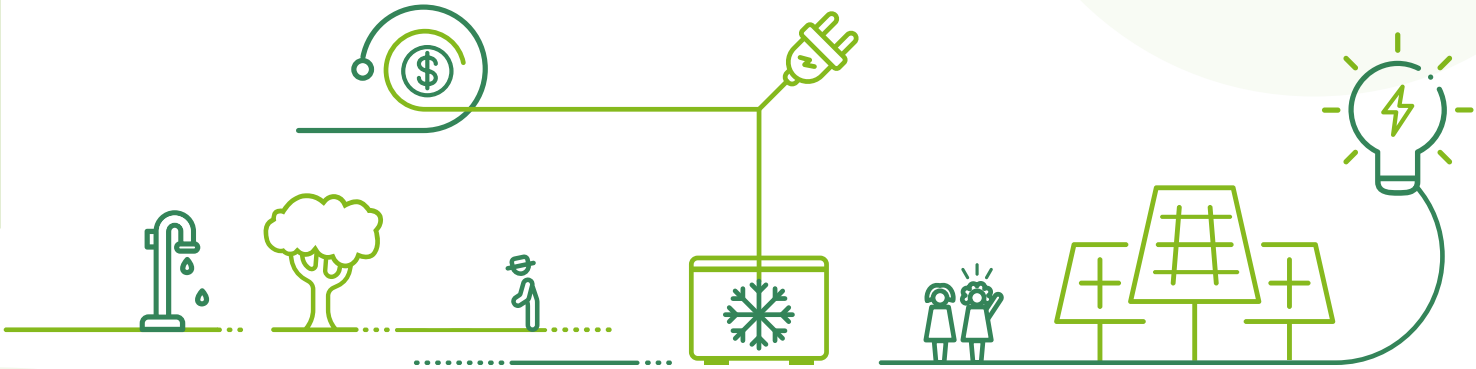
A challenge with solar pumps and SPIS consists in the tendency of farmers to overuse water sources due to the fact that their operational costs are very low compared to diesel pumps or other fossil-fuelled alternatives. Water usage sometimes also increases due to enlargement of cultivated areas resulting from the solar appliances, as described before. This can cause unnecessary stress on an already scarce resource, particularly in dry regions of rural Africa. A technical solution, at least in cases where complete SPIS are promoted, is the usage of drip irrigation systems. These apply water slowly at the root of the plant where it is needed most, thereby reducing runoff and evaporation. Although drip irrigation systems come with additional costs, this makes them very efficient irrigation systems, saving not only water, but also time, labour, and money in the long run.

Apart from technical solutions, training and awareness raising can be used to sensitise farmers to use water efficiently or to simply switch the pump off when additional water is not needed anymore. In GBE's Solar Irrigation Training Programme in Uganda this topic is addressed by the Ugandan government through carrying out corresponding awareness raising measures. Institutionalising such measures in national or regional government bodies or agencies ensures that awareness raising is continued, even after the development intervention has ended. Furthermore, the GBE-intervention in Uganda integrated the Water Use Association (WUA) into the project, to assist in customising water usage to the users' specific locations and requirements. Making use of such local expertise and knowledge of the hydrological situation can further contribute to avoiding the waste of water.

On the other hand, solar pumps have the disadvantage that less water can be pumped during cloudy weather. This means that solar pumping systems come with additional costs for water tanks and that farmers need to be prepared to pump water into these tanks beforehand to channel it to the fields during sunless periods. Also, this can lead to more irregular irrigation, which can limit the choice of crops. These aspects, too, require sensitisation and training to ensure efficient use of the systems.

Explaining the functioning of a solar water pump during training

Finally, several GBE-interventions promoting solar fridges and freezers experienced that users overloaded them with goods, thereby significantly reducing their cooling capacity – another topic which requires sufficient emphasis in corresponding training measures.



Recommendations for reaching scale

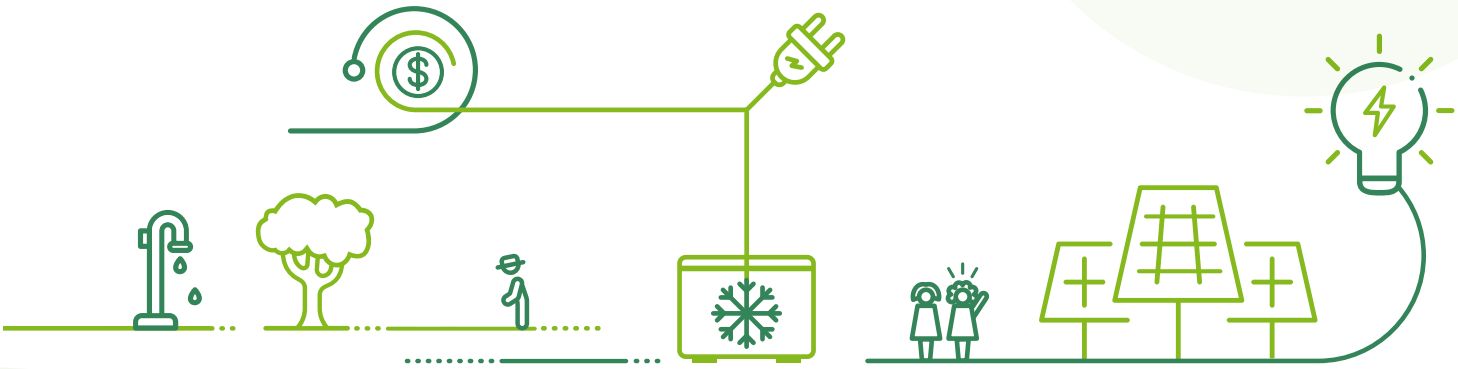
Introducing a **functioning business-case** is often the best pre-requisite for further up-scaling and replication of approaches promoting solar PUE appliances. In the GBE-project in Benin, for instance, several shopkeepers and farmers who purchased PUE appliances under the GBE-intervention have already started buying further solar water pumps and solar fridges to expand their businesses. These additional installations have taken place without support from GBE, some of them financed through the PAYG-scheme offered by the suppliers, others from the income generated by the solar PUE appliances purchased in the scope of the GBE-project.

A recurring theme in several GBE-projects is that implementing successful initial PUE projects with a first group of end-users often generates its own dynamic. Demonstrating that a technology and financing scheme works usually **leads to word-of-mouth recommendations** from users to others, be they farmers, companies or simply friends, family and neighbours, many of whom follow their example. 91 % of the respondents of the quantitative survey state that other farms, enterprises, or cooperatives are interested to learn more about their solar-powered appliances. 87 % of the beneficiaries surveyed recommended the solar technology to others interested and nearly half of them (47 %) know of others who also bought a solar appliance due to their recommendation. With this in mind, solar companies could consider **introducing incentives to promote this kind of advocacy**, for instance by offering a reward for every proven recommendation that leads to an additional loan or sale of a solar PUE appliance.

The fact that some farmers are lending solar pumps they have purchased to other farmers for a fee proves that sharing pumps can work and improves the business case for users. Furthermore, such a rental concept can significantly contribute to increasing interest and dissemination of the technology. It also helps to balance possible envy of farmers who did not directly benefit from GBE-support. Against this backdrop, **actively supporting and integrating such rental schemes** into cooperation projects could contribute to increasing impacts.

Furthermore, a high potential for reaching scale consists of leveraging digital innovations such as **remote monitoring technologies**. These were integrated by two solar companies in the GBE-project in Benin to ensure better after-sales service and payment of PAYG-instalments. These assist the solar sector in improving its efficiency. They can also lower the transaction costs of development partners such as GIZ, but they usually increase product prices (e.g. because remote sensors and contracts with mobile network operators cause additional costs).

Finally, it shall not be forgotten to mention the importance of **involving public institutions** in the implementation of development interventions to facilitate continuation of the approach and further up-scaling. For instance, in the GBE-project in Ethiopia, the Agricultural Research Centre is conducting studies to compare different solutions implemented for solar drying, with the aim of making specific technology recommendations to potential users, while national ministries are carrying out awareness raising campaigns to raise further interest in solar drying. Another example is the RBF-mechanism in Benin which is transferred to the Beninese Agency for Rural Electrification and Energy Management (ABERME) as fund manager to further implement and upscale the scheme beyond the duration of the GBE-intervention.



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